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By Reginald D. Forbes

Watershed Cover and Water Conservation

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A number of years ago I was invited by the Lumbermen's Club of New Orleans, Louisiana, to give a talk to its members on the properties of southern woods. In sending out the notice of the meeting the Secretary of the Club, like all good secretaries, waxed enthusiastic over what the club members were about to hear, and announced that among other things they would learn how to tell apart the wood of the several common species of southern pine. The result was that a good lumberman friend of mine travelled nearly a hundred miles down to New Orleans to learn something that not all the technicians of the Forest Products Laboratory of the Forest Service, which probably knows more about wood than any other organization in the world, had been able to discover over a long period of years. Naturally about the first thing I said in my talk was that I could not unerringly tell apart the wood of longleaf, loblolly, and shortleaf pines, and that so far as I knew no one else could.

The present occasion seems to call for equal frankness on my part. I want to say at once that if any of you expect to hear from me an authoritative statement on the relationship of watershed cover to water conservation, you will be very much disappointed. I can not give you such a statement, and again I must doubt if anyone else can. One hears of course all sorts of conflicting opinions voiced as to the effect of forests and other vegetation on the flow of streams, and every now and then one of these statements finds its way into print. For example, in a preliminary and tentative report on water supplies, made recently to the Regional Planning Federation of Philadelphia, there is a quotation from one Hope Holway to the effect that a fir or pine forest transpires four inches of rainfall annually, a maple forest 8 inches, wheat or grain 10 to 15 inches, and grass 30 to 40 inches. Since the water thus transpired reaches no stream, and contributes nothing to a reservoir, this statement certainly favors trees as a watershed cover. On the other hand, a Yale professor who for several years has been in most successful charge of the large forested holdings of the New Haven Water Company, stated in a recent address that "the net amount of water obtained from a forested watershed in the way of stream run-off is not much different from that secured from an open watershed such as meadow or cultivated land". In the same paper the professor gave the following reasons, among others, for forest rather than agricultural development on the watersheds of public water companies: "one to 25 per cent more precipitation over forested than over open areas, reduced surface run-off, slower melting of snow in the spring of the year, and lessened erosion."

*An address delivered before the annual meeting of the Maryland and Delaware Water and Sewerage Association, at Wilmington, Delaware, May 6, 1931.

I should be the last to challenge the application of any of these statements to our conditions here, for so far as I know there is not a scrap of experimental evidence with which to refute them. By the same token I am reluctant to accept them. Such theories as we may have on this extremely complicated relationship of watershed cover and water conservation are based entirely, I believe, on the experience of investigators in foreign countries, and of a few in the western United States.

That vegetation on a watershed prevents some rainfall from reaching the stream that drains it and the storage reservoir below, is indisputable. Plants appropriate very substantial quantities of water to their own use. Years ago European foresters studied most painstakingly the transpiration rates of several different species of trees in the seedling stage, and one estimate based on these experiments placed the quantity of water used by a mature stand of beech trees as high as 13 inches of rainfall. In 1924 a California investigator found that the willows, alders, sycamores, and grapevines in the river bottom at the mouth of White Water River transpired a quantity of water approximately equal to the evaporation from a free water surface, or a total of about 8 acre feet per year. A professor of forestry at the State College has told me of more than one Pennsylvania farmer who has cleared the forest from the slopes above a well-drained valley, only to have the valley converted into a bog at certain times of the year; his explanation was that the trees had removed from the soil large quantities of moisture, which they gave off into the air in the form of water vapor, and that when they ceased to make this demand upon the soil water it accumulated at the foot of the slope.

Again, there seems to be no question that vegetation, particularly tall vegetation such as trees, intercepts light rains, causing them to be evaporated back into the air without reaching the ground at all. It has been found by experiments in southern California that if all rain were to fall in storms of half-an-inch of rainfall one week apart evaporation would account for practically the total rainfall. This is due, at least in part, to interception of the rain by the crowns of trees or the twigs of brush and lesser vegetation. It should of course be remembered that the surface layers of soil act in very much the same manner as vegetation in facilitating evaporation. Another California investigator is authority for the statement that under local conditions the "soil layer of the most active capillary movement, including a depth of approximately 8 inches, acts in a way analogous to the interception of vegetation. Rains which do not wet below this depth may be lost by evaporation if a few days of clear weather follow storms". In other words the downward percolation of rain through the soil is offset by the upward movement of the moisture in response to the drying of the surface. European investigators have found that once rainfall has actually reached the soil its evaporation is lessened by a vegetative mantle, which not only shades the ground, but forms a surface mulch of dead leaves.

Considering the large amount of moisture which all kinds of vegetation use, it might be concluded that the ideal watershed from the point of view of water conservation is that which has been completely bared of all vegetation, and surfaced with concrete. Even then evaporation from bare surfaces exposed to the full rays of the sun, would have to be compared carefully with the water use of plants. Obviously, however, we need not cudgel our brains over concreted watersheds. They do not seem to be on the market in large quantities. Neither have I heard of any water company which upon the acquisition of a watershed proceeded to remove from it every trace of vegetation. There are sound reasons. Two investigators from the University of Missouri recently compared the percentage of six years' precipitation which ran off seven small sample areas clothed in different types of vegetation. They found that only 11 1/2 per cent of the precipitation ran off the plot kept in bluegrass sod, and from 14 to 27 per cent from plots in various grains and clover. On the other hand they found that 28 to 31 per cent ran off bare plowed soil, and 49 per cent from bare soil which had not been cultivated. Admitting, as I think we all will, the desirability of slow run-off, which permits the rain to percolate downward into the soil and gradually to be delivered to the streams, there can be no question that in this experiment the bluegrass sod and even the seasonal crops, rendered the watershed from two to four times as efficient as if its soils were bare. If any of you gentlemen were "from Missouri", I am certain that from other points of view also you would favor bluegrass sod and the other crops as watershed cover. Because the amount of soil washed away, or eroded, from the different plots during a six-year period was as follows: from the sod, 1-7/10 tons per acre; from clover and grains in rotation, 14 tons; from wheat, 40 tons; from corn, 106 tons; and from the bare soils, plowed or uncultivated from 208 to 247 tons. A reservoir, no matter how large, would not store water very long if more than 40 tons of soil were deposited in it yearly from every acre of its bare watershed!

The Missouri experiment just described gives no comparison at all of forest vegetation with cultivated crops or sod as watershed cover. During the summer of 1929 a series of simple experiments was made in Wisconsin on several soil types under both forest and cultivated crops. The results of this experimentation are recorded in Research Bulletin 99 of the Agricultural Experiment Station of that State. This bulletin includes a most interesting discussion of the effect of distribution of rainfall upon the rate of run-off from different surfaces, and points out that it is sudden heavy rains which cause excessive surface run-off and floods in that state - as probably in every other part of the world. In this study the maximum percentage of the precipitation which ran off the surface, instead of percolating into the soil, was found to be as follows: from under forests, 2.8 per cent; from wild pastures with native grasses, 7.2 per cent; from fields of cultivated hay, 17.7 per cent; and from fields of small grain and corn, fallow land, and seeded pastures (mostly bluegrass), from 25 to 27 per cent. What small quantities of water did run off the surface of forested areas was incomparably clearer than that from the other areas, indicating its freedom from a silt load.

A recent experiment by Dr. W. C. Lowdermilk of the California Forest Experiment Station of the United States Forest Service has gone a long way toward explaining the excessive surface run-off from bare soil. Lowdermilk filled four cylindrical jars with California soils, arranged in layers just as they had occurred in nature. For parts of seven days he allowed perfectly clear water to run into these jars at the top, in such a way as not to disturb the surface soil, and noted the rate at which the water percolated downward. This rate of percolation remained rather uniform. Lowdermilk then replaced the flow of clear water by one of muddy water, prepared by mechanically stirring a small quantity of fine surface soil into the water before it was allowed to flow into the jar. Almost at once the rate of percolation began to fall off. Within six hours it had dropped to but 10 per cent of the earlier rate. The fine particles of soil in suspension in the muddy water had clogged the pores of the surface soil in each cylinder, and prevented the water from finding its way downward through the soil column except at a greatly reduced rate. When rain beats down upon ground devoid of vegetation the fine particles of the surface soil become mixed with the rain, and percolating downward soon seal the pores of the surface soil. Unable to sink into the soil, the rain water then is obliged to run off over the surface of the ground. By intercepting the falling raindrops, both in its foliage and in the layer of litter and humus which it is constantly producing, vegetation plays an enormously important role in keeping the percolating waters clear. Hence, the run-off from soil covered with vegetation is very much less than from exposed mineral soils. Hitherto the layer of humus under vegetation has been regarded merely as a spongy layer of matter, capable of absorbing limited quantities of moisture and delivering it gradually to the soil below.

Still another favorable influence which vegetation exerts on water conservation is in the reduction of evaporation from the surface of the ground. In Europe evaporation from bare soils has been found to account for about half the rainfall, but with wide variations. A forest cover was found in one experiment to reduce this evaporation loss by 60 to 85 per cent. Reduction of wind movement and the mulching effect of the forest humus are the important factors involved.

The foregoing fragmentary evidence on the relation of watershed cover to water conservation may or may not apply under the conditions of the relatively humid eastern United States. It is not surprising that those portions of the United States where the supply of water for domestic, industrial, and irrigation use has already become a matter of grave concern, should be the first to investigate this relation. In parts of California, for example, it is quite possible that the growth of population, and the expansion of farming and industry, will be limited by available water supplies.

As hydraulic engineers, you, more than any other class of citizens, undoubtedly realize that the water supply problem of the East may become at least locally acute. Forty-three per cent of the population of the

Allegheny Forest Experiment Station's territory, which comprises Pennsylvania, New Jersey, Delaware, and Maryland, is living along the Atlantic Seaboard, crowded into the metropolitan areas of New York, Philadelphia, Wilmington, and Baltimore. It did not need last summer's drought to quicken your appreciation of the inadequacy of the water supplies of many growing towns, large and small. Although a few cities, as for example Philadelphia, may look forward to supplying themselves indefinitely, so far as volume of water is concerned, from such large streams as the Delaware River, the majority are turning for their future water supplies to the smaller streams of the region, or to the head waters of the larger streams. The Water Policy Commission of New Jersey states that by 1940 the metropolitan communities of northern New Jersey will require a water development costing between $42,000,000 and $46,000,000, exclusive of the distributing system. I understand that Baltimore, which not long ago completed its magnificent reservoir on the Gunpowder River, is already contemplating spending an additional $30,000,000 in the development of the Patapsco River. Smaller communities are planning proportionate expenditures. And the end is by no means in sight, so long as our metropolitan areas continue to increase in population.

If instead of building new dams and flooding new reservoirs, or tapping distant sources of water supply, you may increase with certainty the flow from your present development, I believe that you and the communities which you represent will be tremendously interested in learning how to do it. It seems to me that the facts which I have presented, fragmentary though they are, are sufficient to warrant your taking a lively interest in the problem of how vegetation on your watersheds may influence the flow of your streams and the volume of water in your reservoirs. Before describing in a little detail the investigations which the Allegheny Forest Experiment Station hopes to undertake in this region in an effort to solve this problem of yours, let me point out a few things that we already know about our conditions here. In the first place, although we know comparatively little about the severity of precipitation during brief periods, we have excellent long-term records of rainfall by months and years. These show that the mean monthly rainfall in the territory of the Allegheny Forest Experiment Station is remarkably uniform; at Baltimore, for example, it runs from about 3 to 4 2/3 inches. This equable distribution of the rainfall not only suggests that we have less need for storage facilities than have many communities of the West and foreign countries, but it also brings out the fact that watershed vegetation exerts whatever influence it may have on streamflow during many months.

Another known fact of great importance in our situation is that, under some circumstances at least, erosion of watersheds, with the consequent silting of reservoirs, presents an extremely serious problem. The Station has in its files some very striking photographs of silt accumulation behind dams erected for water power purposes on the Patapsco River. I am told by the State Forester of Maryland that at comparatively short intervals it is necessary to drain these reservoirs, and at great

expense sluice out the silt which has accumulated behind their dams. The silt sluiced out of one clogs the next below, from which it must in turn be removed, and finally gets down into the harbor of Baltimore, where Uncle Sam wrestles with the problem of its disposal. Deepening gullies in many plowed fields on the watershed of the Patapsco, fields which constitute about 75 per cent of the area, certainly indicate that this erosion is the result of inadequate or unwisely handled cover.

Again, in the solution of this problem it is well to remember that our climate and soils permit a very wide choice of vegetation to use on our watersheds. Anything from excellent grass pastures to splendid forests of hardwoods and conifers may be grown naturally here. However, the percentage of evergreen trees growing in our forests has been so greatly reduced by excessive cutting, and to a lesser extent by fire, that our present forests are composed almost entirely of broadleaf species, which drop their leaves during the winter time and exert comparatively little influence on the melting of snow. To restore the evergreens, should we find we need them, is no easy task. Also the great majority of the forests of our territory are at present even-aged; that is, they have followed the clear-cutting of the forests which preceded them. A mature forest of this type has comparatively little small growth to check wind movement. Therefore, should experiment prove that forests are the most desirable kind of cover for watersheds, the problem may be how to convert our even-aged woodlands into all-aged ones.

A final fact which is worth keeping in mind, when considering conservation of water through proper management of the cover on watersheds, is the swiftly-growing demand for out-of-door recreation by the population of our crowded metropolitan areas. The automobile, running on good roads largely of its own creation, has encouraged the average city dweller to get out into the woods and fields over Sunday and during vacations, and has given values to open land which they did not begin to possess a few years ago. It is my understanding that the average water company at the present time owns or controls only about 5 per cent of its watershed. Should it finally become clear that cover exerts an influence on streamflow of sufficient importance to warrant ownership or control of a much larger proportion of your watersheds, I think it possible that the revenue to be derived from recreational use of the watersheds will help solve the financial problem involved in its acquisition. I am of course assuming that public use may be so regulated that serious contamination of the water can be prevented. If to the revenues to be derived from vegetation on the watersheds may be added those from recreational use, ownership of the greater part of your watersheds would appear to be entirely feasible.

The United States Forest Service proposes to undertake a comprehensive study of the influence of forests on streamflow and erosion throughout the United States. This would be done under an added section - Number 11 - of the McNary-McSweeney Act, under the authority of which the research work of the Forest Service is now developing systematically. The work will be conducted by the various range and forest experiment

stations now covering the United States. The Allegheny Station has asked for funds with which to make a thoroughgoing study of these matters on the watershed of some large city of the Atlantic Seaboard, and on the headwaters of the Allegheny River in the Allegheny National Forest, in northwestern Pennsylvania. The findings should be applicable to conditions over a very large part of the territory. By the employment on each of these two projects of not less than four skilled technical workers, ample clerical help, and proper equipment, we propose to make a determined attack upon all the complex problems involved. A plant physiologist will study the water-use of different species of vegetation, lesser vegetation as well as trees. An expert on soils will study the rate of percolation of rainfall into our varied soils, as affected by surface litter and humus derived from different species of vegetation; also the rate of evaporation from them. On the reasonable but by no means final assumption that forest growth will prove the most desirable form of vegetation a skilled silviculturist will study the methods of converting our present even-aged stands into the probably more desirable all-aged stands of the future, and how to maintain all-aged stands once they are established. He will also study the methods of introducing or reestablishing evergreen species in our hardwood forests. Finally, a trained engineer and meteorologist will study the weather of our region as it bears on the problem of water conservation, including distribution of rainfall over short periods and rate of melting of snow under various kinds of cover; and will handle the numerous problems of stream gauging, silt measurement, and the like. The work of all of these men will be knit into an effective whole by the close coordination of their studies at all times under the direction of a project leader selected from among the technicians named.

The annual cost of these two projects we believe would be about $50,000. Many of the studies must extend over a long period of years before thoroughly reliable results can be obtained. The cost of maintaining such an investigation over a period even as long as 25 years would, we confidently believe, be offset by the saving of a very few feet on the height of a single large storage dam.